Amendments to the Specification:

Please replace the current title with the amended title as follows:

APPARATUS ~~AND METHOD~~ FOR CLEANING PURPOSES <u>USING PARALLEL FLOW</u>

Please replace the paragraph bridging pages 15 and 16 with the amended paragraph as follows:

The present invention provides a new and unique cleaning apparatus that can be used for cleaning surfaces from contaminating particles [[by]] using [[of]] a dry aero-mechanic method of cleaning. For the purpose of the present invention the term "cleaning" refers to removal of any kind of contaminants, for example particles or liquid, and to drying of a surface. A surface cleaning apparatus, as will be shown herein in several preferred embodiments, comprises a housing provided with cleaning head unit having an outlet that is connected to high pressure source and through which air (or other gas) is injected and preferably through other passages air is sucked by using vacuum forces.

Please replace the first full paragraph on page 20 with the amended paragraph as follows:

Figure 1c schematically illustrates a cross sectional view of the elongated cleaning head unit 10 shown in Figure 1a. The cleaning head unit 10 has a mirror symmetry structure. However, in most aspects the cross sectional view of the round-shaped cleaning head unit 10a shown in Figure 1b is similar. The cleaning head unit 10 has basically two different types of pipes connectors, one connector or more for high-pressure supply 20 and one connector or more for vacuum supply 30. High pressure passage 22 fluidically connects the high-pressure supply 20 with the pressure outlet 21 at the cleaning head unit 10 facing surface 11, and vacuum passage 32 fluidically connects the vacuum supply 20 with the vacuum outlet 31 at the facing surface 11 of the cleaning head unit 10. The facing surface 10 is positioned substantially parallel and in a close proximity to the surface 99 of the object 100 to be cleaned. The gap between the facing surface 11 of the cleaning head

unit 10 and the surface 99 to be cleaned is denoted hereafter by the letter Greek letter "ε". The outlets 21,31, and the lips 12 define a miniature chamber with the facing surface 11. The lips 12 are the edges of the wall that separate the high-pressure passage 22 from the vacuum passage 32. The lips 12 have a typical width "b", the high-pressure outlet 21 having a typical width "a", and the vacuum outlet 31 having a typical width "d". The cleaning head unit 10 has also outer walls with rims 13 having a typical width "c". The outer wall edges 13 may optionally be included in the facing surface 11, but it can also be designed at a distance ("e") from the surface 99, which is larger than "ε". It is an option to provide a flow restrictor 23, like a SASO device (which is a mechanical flow restrictor, see WO 01/14782, WO 01/14752 and WO 01/19572, and corresponding US Patent 6,644,703 and US Patent 6,523,572, all incorporated herein by reference), or a pressure control valve (usually electrically operated) inside the high-pressure passage 22, in order to provide a fluidic return spring nature to the cleaning head unit. To save vacuum resources, it is an option to equip another, different flow restrictor 33, preferably also [[s]] <u>a</u> SASO nozzle of smaller aeromechanical-resistance with respect to the SASO nozzle that is selected for the high pressure passage, or other flow control valve inside the vacuum passage 32.

Please replace the paragraph bridging pages 23 and 24 with the amended paragraph as follows:

The high removal forces are generated at the throat section area along a very short length. In order to maximize cleaning performance, the flow-field can be manipulated. Reference is now made to Figure 3a depicting an enlarged portion of the sharp edge throat section shown in Figure 1b. Figure 3a schematically illustrates a focused cross sectional view a sharp throat section 18b <u>(see Fig. 1e)</u>, one of two opposing throat sections of the cleaning head unit with sharp lips 12b <u>(see Fig. 1e)</u>. The flow is accelerated rapidly from the high-pressure passage 22 through the throat section 15 created between the surface 99 to be cleaned and the sharp lips 12b of the wall 16 between passages 22 and 32, and finally sucked away through the vacuum passage 32. The sharp throat section 15 has a tiny width "ε". When, with respect to another preferred embodiment of the present invention, the lateral width "a" (the lateral scale) of the high-pressure passage 22 (at outlet 21, close to the

throat section area), is large with respect to "**ε**", a low-speed flow towards the surface 99 is developed inside high-pressure passage 22, as indicated by the small arrow **41**, thus the dynamic pressure at outlet 21 (close to the surface 99), is very small with respect to the stagnation pressure. Accordingly, a "radial" flow pattern **42** is developed. Where the fluid start to accelerate only at the throat-section area.

Please replace the second paragraph on page 25 with the amended paragraph as follows:

Reference is made to Figure-4a, illustrating a schematic close view of a single spherical particle 50 adheres to the surface to be [[clean]] <u>cleaned</u> 99 and subjected to a lateral flow characterized by stream-lines 59. This is a miniature close view of the flow regime close to the particle that is located at the throat section zone (not seen in the drawing). As the particle having a three-dimensional character poses as an obstacle to the flow, the stream-lines 59 open out also in three-dimensional manner (only one stream line up wise is drawn, for brevity). Just downstream of the particle, flow separation 56 occurs and a miniature wake flow 55 is generated. A pressure removal force 53 is generated when the flow stops just before the particle, a stagnation zone 52 is developed where high recovered pressure forces are acting (stream-wise), on the particle. On the other side, much lower pressure is acting on the particle at [[it]] <u>its</u> downstream side that is subjected to the separated flow. Moreover, as the flow is a sonic flow, a standing shock wave 58 attached to the top surface of the particle can be formed as the flow is further accelerated (to low super-sonic speeds). In that case, the pressure on the wake side is further ~~reduces~~ <u>reduced</u>. The net stream-wise pressure force is, generally speaking, the difference between the pressure acting on the upstream side to the pressure acting on the downstream side of the particle. The stream-wise shear force 54 acting on the top particle 55 top surface <u>is</u> attributed to viscosity. Accordingly it is related to the thermodynamic properties of the gas (the viscous coefficient) and depends on the normal (to the surface) velocity gradients.

Please replace the paragraph bridging pages 25 and 26 with the amended paragraph as follows:

These two complementary stream-wise removal forces generate a resultant side force that tends to disconnect the particle from the surface by slippage. However in many cases this is not the dominant removal mechanism, as the particle can firstly disconnect by rolling with respect to the point of rotation 51, as it is subjected to aeromechanic moments (notice that the shear force span is larger as much as twice with respect to the pressure force). When the particle 50 is a perfect sphere, the adhesion force cannot provide much resistance to the aeromechanic moments as the span of the adhesion forces with respect to the point of rotation 51 is small. Figure 4b shows a similar situation as shown in figure 4a, but the particle 50a is of non-regular shape. In that case, with respect [[the]] to the shape of a specific particle, the point of rotation 51a is offset with respect to the adhesion forces. Accordingly the adhesion force can provide resistance to the aeromechanic moments as the span of the adhesion-forces with respect to the point of rotation 51a can be significantly large. When such adhesion moments are developed, the removal forces needed to disconnect the particle by rolling mechanism may be extremely larger with respect to the removal forces needed to disconnect a similar in size spherical particle.

Please replace the paragraph bridging pages 29 and 30 with the amended paragraph as follows:

Figure 7 a-d illustrates some proposed relative motion effects. Figure 7a illustrates a basic relative scanning motion where the cleaning head unit 10 travels in a lateral direction 71 substantially parallel to the most effective cleaning directions 72 (two opposing directions are acceptable if the cleaning had unit has a symmetric structure), thus geometrically speaking, the coverage area 73 during the cleaning process is believed to be the wider available with respect to the cleaning head unit length. Figure 7b illustrates a case where the cleaning head unit 10 travels in a lateral direction 71 that is not parallel to the most effective cleaning directions 72, thus geometrically speaking, the coverage area 73 during the cleaning process is reduced. However also when an angle of 45° is applied between directions 71 and 72, still more that 70% of the scanning efficiency is maintained. In order to optimize the cleaning process efficiency, a setup where the cleaning apparatus is equipped with two orthogonal cleaning head units is suggested. Figure 7-c illustrates such a setup where two cleaning head units 10 (where the removal force directions are denoted

by the arrow 72), and 10t (where the removal force directions are denoted by the arrow 72t), are positioned orthogonally and both are oriented at an angle of 45° with respect to the scanning motion 71. The reason for such a setup is evident when reviewing Figure 7d. This figure schematically illustrates a common situation where an elongated particle 50 lying over the cleaning surface 99 needs to be removed. When the removal force acts on that elongated particle on its short aspect (74a) the resistance to the rolling mechanism of removal is relatively small, but when the removal force acts on the elongated aspect of the particle (74b), resistance to the rolling mechanism of removal is significantly increased. Accordingly, the use of bi-directional cleaning process as illustrated by the setup shown in ~~figure 73~~ figure 7d, improves the cleaning process. Another alternative for this setup is to use one cleaning head unit but perform dual stage cleaning process where in between the two cleaning stages the orientation of the cleaning head is altered. It has to be emphasized that for the purpose of the present invention, the phrase "relative scanning motion" means that either the cleaning head unit is kept at rest and the object to be clean is moved, or the cleaning head unit is moved and the object to be clean is kept at rest, or when a more complex motion is implemented and both cleaning head unit and the object are moved in relative motion between them.

Please replace the first full paragraph on page 30 with the amended paragraph as follows:

Other important issue with respect to the present invention is the thermal conditions that exist during the cleaning process. Air or other gas that is used in the cleaning process can be pre-heated. In that case, removal forces that depend on the thermodynamic properties of the gas (such as viscosity or density) are augmented or at least do not severely deteriorate. Nevertheless, the main reason for heating the gas is for reducing the adhesion forces. If the heated air heats the particles and the surface to be [[clean]] cleaned underneath it to a temperature of more than 100°C, water trapped between the particles and the surface evaporates. As the water disappears, the capillary portion of the adhesion force [[not]] no longer exists. Capillary force is the significant part of the adhesion force and accordingly it makes the task of particle removal easier when it disappears. Another alternative is to pre-heat the object to be [[clean]] cleaned and/or to heat it during the

cleaning process in order to evaporate the water and to diminish significantly the adhesion force. Heating can be performed using an in-contact platform where heating elements are used (heat conduction mechanism), or by pre-heating air that is used to produce an air-cushion, when a non-contact platform is used (heat convection mechanism). On the other hand, it is also an option to spray the surface with water to reduce the capillary forces, or to apply other solutions, in order to weaken the adhesion forces. There are many known commercial solutions that are used for that end. However such an approach that involves wet conditions around the particles is not preferable as it leads to a semi-dry cleaning process and it is difficult to exercise. In addition, it is also an option, with respect to reducing adhesion force, to add ionizer to the flow in order to reduce the electrostatic adhesion force.

Please replace the paragraph bridging pages 30 and 31 with the amended paragraph as follows:

In order to maximize removal forces, it is an option to provide periodic fluctuations to the flow, to be effective at the throat section area. It can be done by acoustic means or by using electromechanical means (including piezoelectric elements). From an aerodynamic point of view, periodic (time dependent) fluctuations affect temporarily the boundary layer thickness and the velocity gradients close to the surface. Moreover, periodic fluctuation frequencies can be correlated with the miniature scales of the smaller particles where the removal task becomes harder. It means that high frequencies can be effective for removing miniature (submicron) particles, but the operational frequencies must be lower than a critical frequency, since fluid acts like a low-pass filter and does not ~~response~~ respond to extremely high frequencies.

Please replace the second paragraph on page 33 with the amended paragraph as follows:

Figure 9b illustrates, in accordance with another preferred embodiment of the present invention, a circular non-contact platform where a small traveling cleaning head unit 10a having a round outlet 21 of the high pressure passage (of the cleaning head unit 10), is integrated in a round non-contact platform 90 having an active surface 91. The

cleaning head unit 10a is of much smaller size with respect to the radius of the non-contact platform 90. The facing surface 11 of the cleaning head unit 10a is included in the active surface 91 of the non-contact platform 90. In order to provide radial scanning motion, the cleaning head unit is moved during the cleaning process along a radial slider 92. In this case, coverage of the entire surface to be cleaned is completed by simultaneously turning the object to be [[clean]] cleaned (not seen in the figure).

Please replace the paragraph bridging pages 33 and 34 with the amended paragraph as follows:

Figure 9c illustrates, in accordance with another preferred embodiment of the present invention, several options where more than one cleaning head units are integrated within the non-contact platform 90, where the facing surface of each cleaning head unit is incorporated in the active surface 91 of the non-contact platform 90. One option is to use several cleaning head unit segments 10f arranged in a radial orientation but at different angles, where each segment cleans an annular slice and all the segments together provide full coverage of the surface to be cleaned. Still, coverage of the entire surface to be cleaned may also be completed by turning the object to be [[clean]] cleaned (not seen in the figure). Another option is to apply removal forces acting in two substantially perpendicular directions, by replacing each of the integral segments 10f with two segments 10g, having substantially perpendicular orientation (only the central slice is shown). In this case cleaning process efficiency may be improved as explained with respect to Figure 7d hereinabove.

Please replace the paragraph bridging pages 34 and 35 with the amended paragraph as follows:

Figure 10b illustrates, in accordance with another preferred embodiments of the present invention, a setup having circular geometry for front-side cleaning where a stand-alone cleaning head unit 10a is facing the surface 99 of the object to be cleaned that is supported by a non-contact platform 90 of the dry cleaning system. In this setup (and also with respect to figure 10c and 10d), it is preferable to implement the Pressure-Air (PA)-type supporting air-cushion, or the Pressure-Vacuum(PV)-type (vacuum preloading) air-cushion that clamps the object at bi-directional manner (see PCT/IL02/01045,

incorporated herein by reference). In this setup, either the cleaning head unit 10a is rotating, or the object to be cleaned 100 is rotating, or both, in order to provide the relative scanning motion 94r. Rotational motion to the round object 100 can be provided by a rotating mechanism such as a drive-wheel 95 attached to the edge of the round object 100 (such as silicon wafer). Other rotational drive mechanisms that may alternatively be implemented, include rotating circumferential-ring that clamps the object or any other in-contact mechanism that clamp the object from its backside. Another option is to apply a totally non-contact fluidic mechanism that ~~imposed~~ imposes rotating shear forces to rotate the object. Other mechanism may also be used, remaining within the scope of the present invention.

Please replace the paragraph bridging pages 34 and 35 with the amended paragraph as follows:

Figure 10d illustrates, in accordance with another preferred embodiment of the present invention, a setup having circular geometry for cleaning both the front-side and the backside of a round object. This setup includes both a cleaning head unit 10a for cleaning the front-side 99f of object 100, and an opposing integral cleaning head unit 10, integrated within the platform 90 of the dry cleaning system, for cleaning the backside 99b of object 100. The object to be cleaned 100 [[that]] is supported by a non-contact platform 90 of the dry cleaning system. In this setup, only the object to be cleaned 100 is rotating in order to provide the relative scanning motion 94r. Yet again, rotational motion to the round object 100 can be provided by a rotating mechanism such as a drive-wheel 95 that is attached to the edge of the round object 100 (such as silicon wafer). Other rotational drive mechanisms were disclosed with respect to figure 10b.

Please replace the first full paragraph on page 36 with the amended paragraph as follows:

Without derogating the generality, figures 10f-j illustrates setups employing linear scanning motion suitable for the FPD industry (wide-format thin substrates). where non-contact platforms are implemented. Figure 10f illustrates, in accordance with another preferred embodiments of the present invention, a setup having rectangular geometry for

front-side cleaning of rectangular thin substrates such as FPD, where an elongated cleaning head unit 10a is facing the front-side 99 of the object 100 to be cleaned that is supported by a non-contact platform 90 of the dry cleaning system. The cleaning head unit 10a may be divided to several sectors 10s. This case is similar in most details to the setup described in figure 10b, but here linear motion is provided. In this setup (and also with respect to figures 10g - 10j), it is suggested to implement the supporting PA-type air-cushion, or the PV-type (vacuum preloading) air-cushion (see PCT/IL02/01045, incorporated herein by reference) that clamps the object at a bi-directional manner. In this setup, either the cleaning head unit 10a is linearly moved, or the object to be cleaned 100 is moved in linear motion, in order to provide the relative scanning motion 94c. Linear motion to the object 100 can be provided by using various types of linear-motion systems and grippers. Another option is to apply a totally non-contact fluidic mechanism that ~~imposed~~ imposes shear forces to linearly drive the object.

Please replace the second paragraph on page 39 with the amended paragraph as follows:

Reference is now made to Figure 11 illustrating, in accordance with a preferred embodiment of the present invention, a dry cleaning system 400. The dry cleaning system 400 has a base 200 having an internal volume large enough to host different components and subsystems in a compact manner. On top of base 200, the dry cleaning system 400 has a PV-type non-contact supporting platform 210. The non-contact supporting platform 210 rotates in direction 225 driven by a driving mechanism 220. During the cleaning process, the platform 210 is in relative rotational motion with respect to base 200 and to the cleaning head unit 110. Platform 210 may be supported by mechanical or aeromechanical means to balance its body-weight. The object to be cleaned 100 is laterally clamped by three [[3]] edge elements 212. Elements 212 provide also centricity alignment for object 100 with respect to the center axis 219 of the non-contact platform 210. Elements 212 serve also as landing pins for loading and unloading of object 100. The object to be cleaned 100 is vertically supported without contact by PV-air-cushion that is provided by non-contact platform 210. Proximity sensor 213 is attached to the non-contact platform 210 in order to sense the distance between the facing surface of the non-contact platform 210 and the

backside surface of the object to be cleaned 100, to enable close loop control of the gap of the supporting air-cushion. Heating elements 240 and temperature sensor 241 are integrated within the platform 210.

Please replace the fourth paragraph on page 40 with the amended paragraph as follows:

Central control unit can be an external unit or it may be internally installed inside base 200. Accordingly valves 121 and 131 as well as valves 221 and 231 can be assembled inside base 200. In addition, an optical scanning device 450 may be incorporated with the cleaning system 400 to provide either ~~lateral~~ the location of the contaminating particles (in particular when point-to-point cleaning process is applied) and/or to provide pre- and post-process analysis of the cleaning process.